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Fort Riley Earth Penetration Program: Site Selection and Geologic Characterization (U)

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John C. Eichelberger

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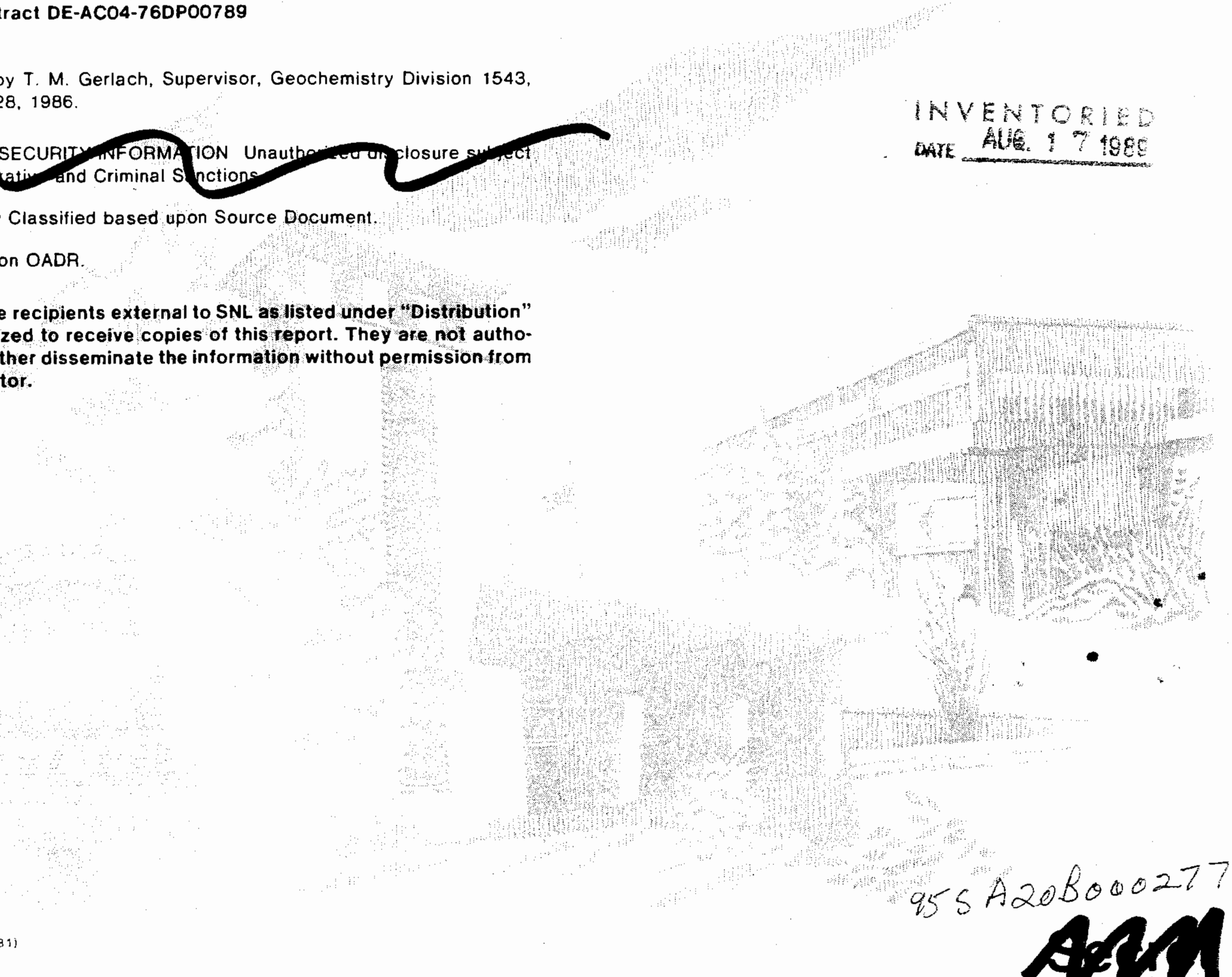

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ACKNOWLEDGMENT (U)

The investigation reported herein was conducted for the U.S. Army Engineering Waterways Experiment Station (WES) by the Sandia National Laboratories under MIPR number A35200-5-0011, dated 8 March 1985. It was sponsored by the Defense Nuclear Agency (DNA) as a part of Task Code RSRB, Work Unit 00037, "Earth Penetrator Research." The work was technically monitored by Dr. Behzad Rohani of the Geomechanics Division, Structures Laboratory, WES.

CONTENTS

1. Introduction

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[redacted] While the behavior of EPWs in soils and other unconsolidated overburden materials is believed to be well understood, the behavior of EPWs in hard rock is not. It is clear that where very high-strength rocks are present near the surface, EPW survival is unlikely. Two factors are thus important in assessing EPW survival. One is overburden thickness.

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[redacted]. The second factor is weathering. In most cases, an intervening zone of altered rock exists between the low-strength residual or transported soil and high-strength basement.

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[redacted] Weathered zones may be highly heterogeneous in terms of strength, because they contain fractured or rubblized zones interspersed with high-strength blocks. The behavior of EPWs in such environments, which might induce high lateral loads on a vehicle despite low overall strength, is unknown.

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[redacted] A meeting of the DNA Earth Penetrator Research Planning Committee on October 10, 1984 identified the following steps (Rohani, 1984): [redacted]

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2. Characterize the selected site.
3. Conduct large-scale EPW experiments.
4. Analyze test data.

This document reports on results of steps 1 and 2. A companion report documents steps 3 and 4 (Young, 1986).

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[redacted] This approach is hampered by limited data, both in terms of source information and potential U.S. sites. Weathering is a group of complex chemical and mechanical processes, dependent on rock type and climate. Moreover, the weathered zone is of limited economic importance compared to the shallower soils and deeper stratigraphy. Consequently, no rigorous system for describing weathering exists. Because of limited information on the products of weathering, it is thought to be advisable to obtain as close a match as possible in original lithology, subsequent burial, and current climate.

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[redacted] Such rocks develop in environments distributed in bands parallel to the shoreline on a gently sloping continental shelf (Fig. 3). Shales accumulate in the darker, cooler deep portion of the slope, carbonates in the warm aerated shallow environment but away from the sediment-laden shoreline, sandstones (and sometimes red shales) in the high-energy, near-shore environment, and coal in swamps above sea-level. These deposits are vertically juxtaposed in thin beds by transgression and regression of the sea, sweeping the shoreline and the shoreline-related environments rapidly across many hundreds of miles of shelf. [redacted]

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[redacted] Of the order of 100 widely correlative cycles are recognized through the 330-240 m.y. period, indicating a typical 10^6-year period (Crowell, 1978; Ross and Ross, 1985; Heckel, 1986). The widespread character of these cycles, their time scale, and their coincidence in time with glacial deposits over the thermally-isolated south pole occupied by the super continent of Gondwana, suggest that the cycles are glacially induced. Growth of large ice caps caused slow regression of the sea, while melting caused rapid transgressions. Small-scale, ice-controlled sea-level oscillations likely led to the characteristic thin-bedded character of the limestones and their associates.

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requirements are most easily met on a military reservation where artillery is used.

Recovery of the EPWs is a further test requirement, and a significant component of project costs. Recovery costs and difficulty increase rapidly with depth. Thus, it is desirable to minimize depth of penetration, insofar as the technical objectives of the test can be made at shallow depth.

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us tests have been conducted in unconsolidated materials described collectively as overburden, and the behavior of EPWs in such environments can now be predicted. Further, the effect of overburden can be incorporated into the test by adjusting the muzzle velocity of the penetrator. For these reasons, and because the presence of overburden would hinder both site selection and penetrator recovery, it was decided to select a site at which as little overburden as possible was present. By restricting overburden thickness, expected depth of penetration is limited to less than 30 ft. Recovery at these depths is accomplished by digging with a backhoe, and if necessary by blasting. Selection of a site where the water table is deeper than the expected penetration depth greatly facilitates these operations.

A summary of siting criteria is presented in Table 1. These criteria represent the consensus of the site selection committee (Table 2), which reviewed site screening decisions as the site search progressed.

3. Site Selection

The first step in site selection involved delineation of regions of interest within the United States. As can be seen in Figure 4, the largest

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The most useful references were the Defense Mapping Agencies' (DMA) map of major military installations (DMA, 1979), the geologic map of the United States (Bayer, 1983), and the regional geologic maps published by the American Association of Petroleum Geol [redacted]

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till provides thick cover in much of the northern half of central U.S. (Fig. 4), and the insoluble residue from weathering of carbonate sections has accumulated to great thickness in humid, poorly drained areas such as the Ozark Dome.

The initial reconnaissance search led to selection of four promising sites for further study (Fig. 4). A comprehensive literature search was conducted for these sites utilizing Georef, Geoarchive, the Defense Technical Information Center, and the National Technical Information Service. In addition, complete topographic map coverage and, where available, geologic map coverage were obtained. A summary of the results is presented in Table 3. Ft. Riley was selected as the primary area for detailed investigation. [redacted]

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Overburden is thin to non-existent. Use of artillery and explosives on the reservation is routine. However, in order to provide a broader perspective on the geology of Ft. Riley and to identify any disadvantages from restricting testing to the military reservation, it was decided to examine other potential test areas in the northeast Kansas region. This parallel investigation was conducted by Glen Rawson (RDA), and results supported selection of the Ft. Riley site.

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6. Borehole Television Results

All seven holes were logged with a borehole television camera by Richard Hunt (WES) shortly after drilling. Written logs of the four NX holes made by him from the videotapes are appended to this report. The camera provides a complete vertical record of a traverse down the hole consisting of a 1.5 x 2 in. field of view, supplemented by the operator's narration.

In general, the camera gives the same record as a visual inspection of the core, but degraded by limited image quality, lack of color, and incomplete records due to murky water in the hole and/or mud cake on the walls. However, it provides the most reliable record attainable of natural fractures in the subsurface. Many of the fractures noted in the core are induced by the coring process and during extraction of core from the core tube. This can be seen by comparing small-diameter core with large-diameter core from a nearby hole. Further, highly fractured sections yield no core at all. Other features distinguishable in the television record are reflectivity of the surface (dark or light), texture (rough or smooth), bedding planes, vugs, and fossils. On these bases, the main upper units of the holes could be distinguished. The most weathered material appears as an area of irregular intersecting fractures and washouts. But even here, occasional primary rock features such as through-going bedding planes and vugs are visible.

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7. Strength Test Results

Unconfined compression tests were conducted on selected waxed and unwaxed cores from the upper 30 ft of the NX holes, by J. C. Schumacher (WES). Results are summarized in Table 4, and Schumacher's report is appended to this document. During drilling, intact core samples of at least 5-in. length were selected at approximately 5-ft intervals, wrapped in foil, and coated with wax to preserve their original water content (of course, this water content is somewhat altered by the drilling itself). Additional samples (unwaxed) were selected later to improve data coverage of the

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[redacted] Some damage is done to the core during drilling and during extraction of the core from the core tube. Consequently, the fractures observed in core exceed those originally present, though often the induced fractures can be identified. A more important consideration, particularly at Ft. Riley, is that highly fractured materials do not yield core. Hence, data from core samples are skewed toward higher strength strata. The downhole camera provides a means of observing these weaker sections, but information is degraded by limited image quality, lack of color, and concealment of the walls by mud. The combination of core and television results is important for a complete description of the section. Finally, trenches dug during EPW recovery give an areally extensive vertical cut. These fresh, undried surfaces provided an indication of the significant proportion of clay-rich strata within the weathered zone, although the splashing of mud on these surfaces tended to cause overestimation of the extent of the weak layers. The trenches also showed that there is an abundance of water above the stable water table as measured in the core holes. [redacted]

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Figure 5. Generalized sedimentary section for Fort Riley, from coring results (this paper) and Zeller (1968).

Figure 6. Map showing distribution of geologic and geographic features considered in selection of a test area on Fort Riley.

Figure 7. Map showing locations of core holes drilled during July 1985 to characterize the Fort Riley test site. The site is Site 1 on Figure 6. The area shown is located in the Training Area #35, NE 1/4, Section 31, T10S, R6E. It is within the Fort Riley NE Quadrangle, U.S. Geological Survey 7.5 minute topographic series. Hole numbers are last three digits of U.S. Army Corps of Engineers, Missouri River Division designation: DC-85-XXX.

Figure 8. Lithologic results of the core holes shown in Figure 7. Two digit numbers (X.X) denote unconfined compressive strengths from Schumacher (Appendix B). Arrow indicates center of vug-rich zone.

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RQD was not measured during drilling but was calculated by the author from core logs by R. Bader.

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Figure 4

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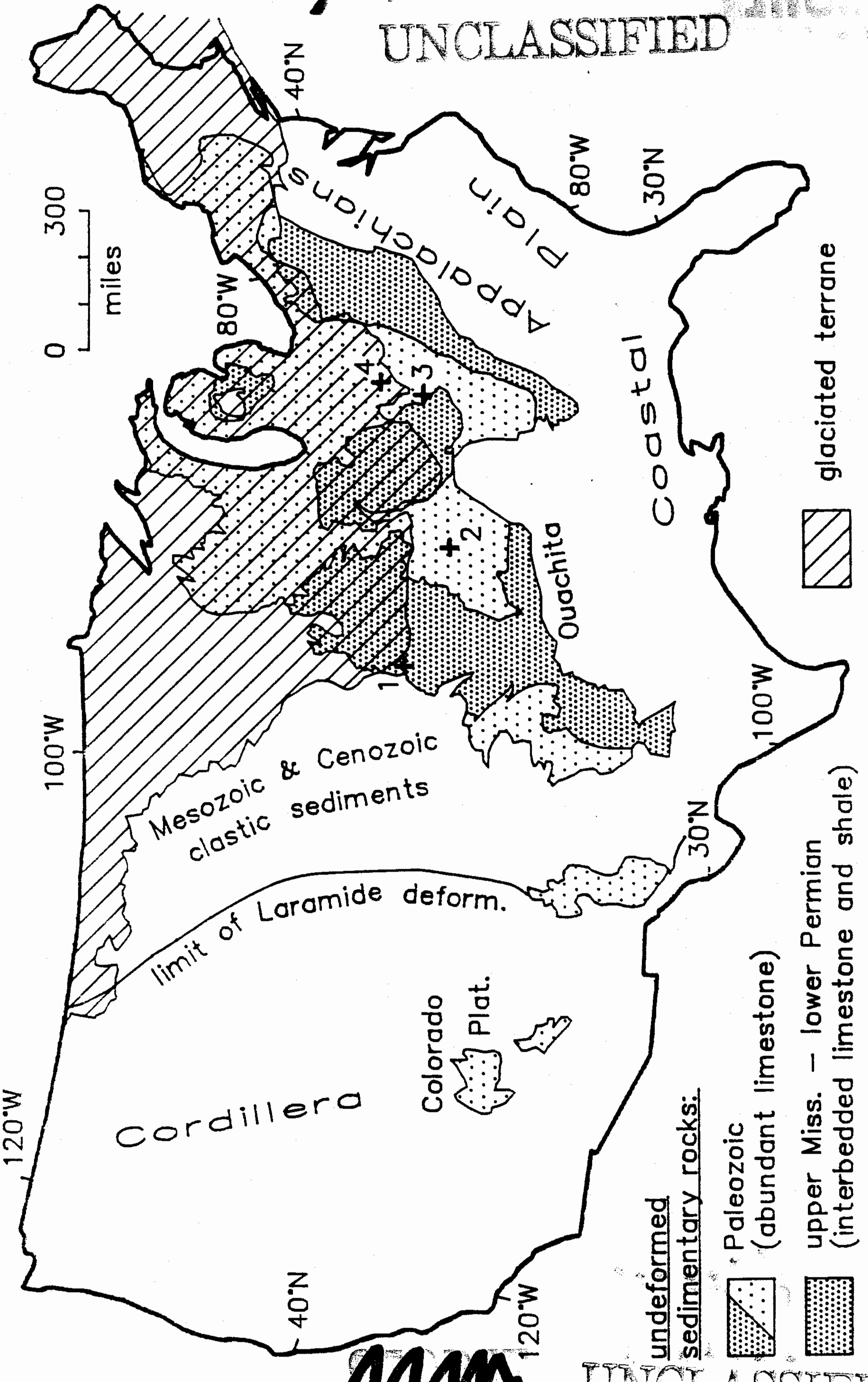

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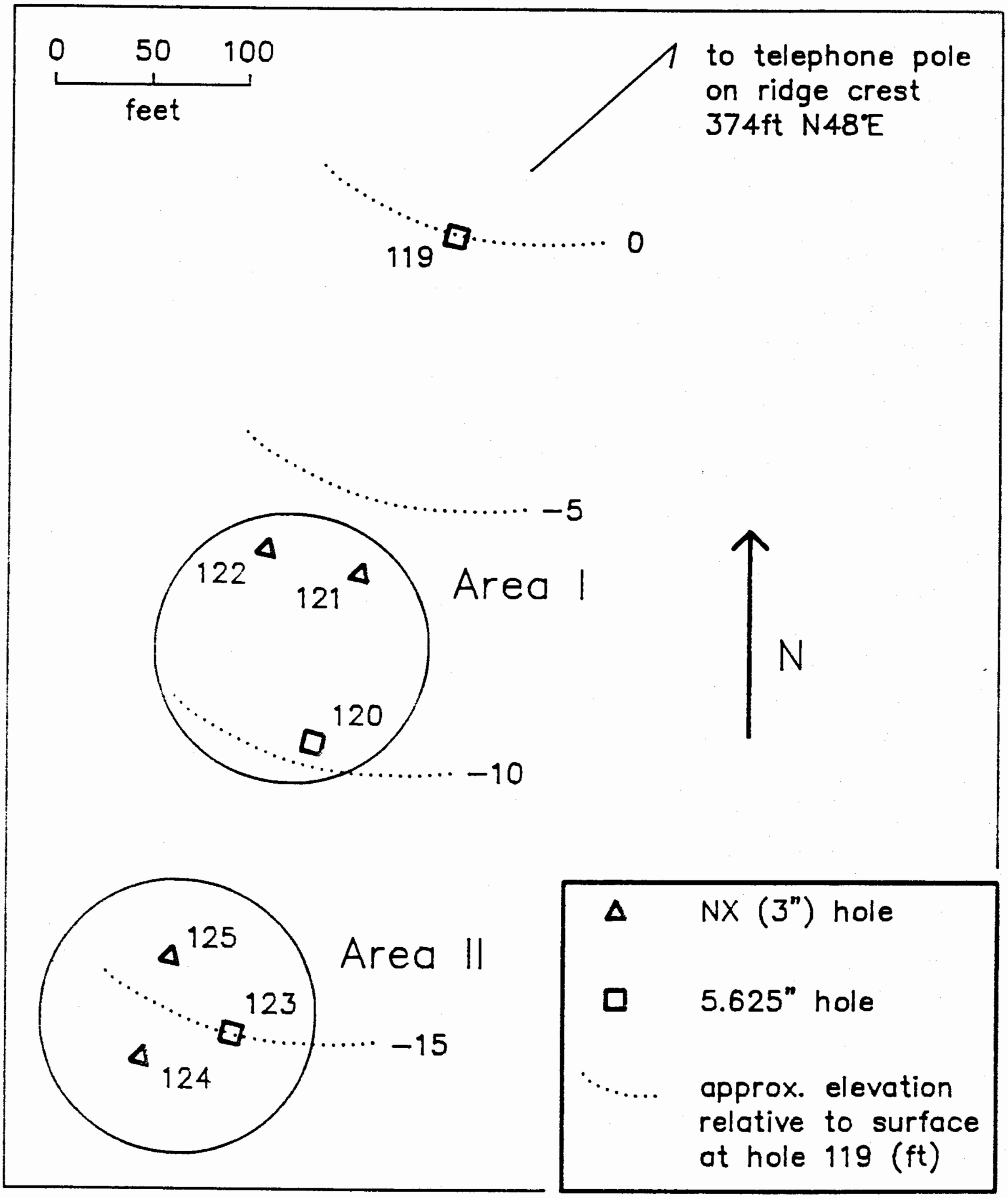
Figure 7


0
50
100
feet
to telephone pole
on ridge crest
374ft N48°E
119
0
-5
122
121
Area I
120
-10
N
125
Area II
123
-15
124
△ NX (3") hole
□ 5.625" hole
approx. elevation
relative to surface
at hole 119 (ft)

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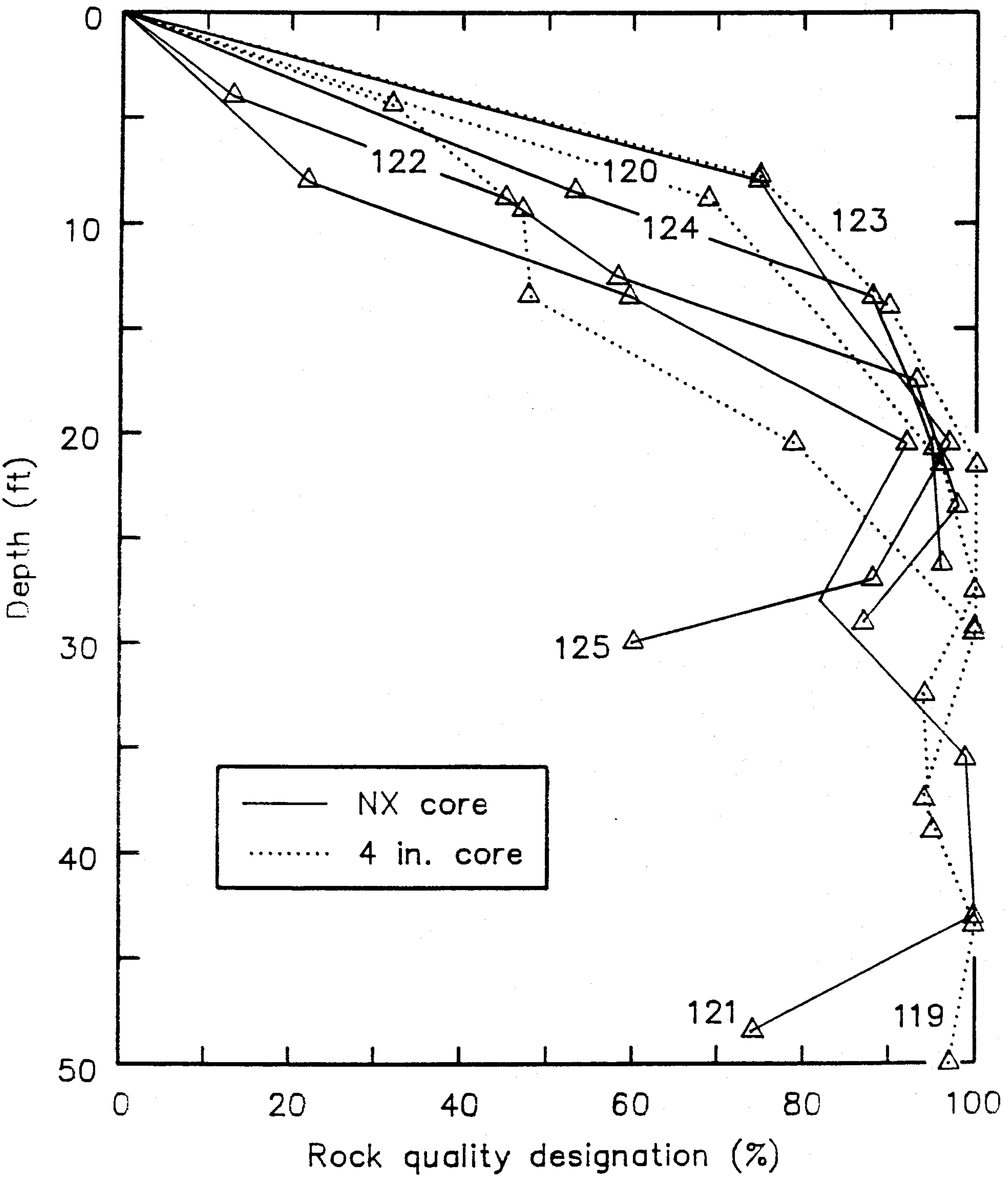

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APPENDIX A

BOREHOLE TELEVISION LOGS FOR BORINGS DC-85-122, 124, and 125, FORT RILEY, KANSAS

by

Richard Hunt
U.S. Army Engineer Waterways Experiment Station
Vicksburg, MS 39180-0631

January 1986

Prepared for: Defense Nuclear Agency
Washington, D.C. 20305
Under Task Code RSRB, Work Unit 00037

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BORING DC-85-122, FORT RILEY, KA

NX Borehole film interpretations:
Photographed between 5.0-25.0'; hole was cased to about 6.0' deep.

Depth (ft)	Description
(6.0-8.2)	light gray-white rock with dark gray zones; rock appears fractured at random and weathered; fragments of rock are missing from side wall.
7.5	Joint, strike N20°W, dip 20°NE, tight, irregular
7.6	Joint, strike N85°W, dip 20°S, tight, irregular
7.7	Joint, strike N30°W, dip 20°SW, tight, irregular
8.1	bedding joint, approximately horizontal, tight, irregular
(8.2-12.4)	light gray-tan rock with numerous vugs and numerous bedding joints, appears weathered.
8.6-10.3	27 bedding joints, about horizontal, tight to 1/32" wide filled, irregular
(12.4-16.4)	light gray-tan rock with numerous vugs, no joints
(16.4-17.9)	Alternating light gray-tan and medium gray lenses with bedding about horizontal
17.6	bedding joint, horizontal, 1/32" partly open
(23.2-25.0)	light gray-tan rock
24.5-25.0 (Bot.)	numerous about horizontal bedding joints, tight, irregular and have limonite(?) staining.

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BORING DC-85-124, FORT RILEY, KA

NX Borehole film interpretation
Photographed from 4.0' to 25.0'; hole was cased to about 6'. Bearings are from magnetic north.

Depth (ft)	Description
(6.0-7.2)	light gray-white rock, appears weathered
6.5	bedding joint about horizontal, tight
(7.2-.3.8)	light gray-tan and medium gray thin bedded rock with numerous bedding joints.
7.2	horizontal bedding joint, 1/32 to 1/16" partly open, irregular
7.4	horizontal bedding joint, 1/32 to 1/16" partly open, irregular
7.8	2 horizontal bedding joints 1/32, tight
7.9	horizontal bedding joint 1/32-1/16" partly open irregular
8.2-9.2	18 closely spaced horizontal bedding joints that range from tight to 1/16" partly open, most are irregular.
9.4	horizontal bedding joint, 1/16" partly open
9.4-9.6	joint, strike N40°W, dip 35-40°NE, 1/16" partly open
10.0-10.8	numerous closely spaced horizontal bedding joints, tight to 1/16" partly open, most are irregular
11.5	horizontal bedding joint 1/32"-1/16" partly open, irregular
11.6	horizontal bedding joint 1/32"-1/16" partly open, irregular
11.7	horizontal bedding joint 1/32" partly open, irregular
12.0	horizontal bedding joint 1/16" partly open, irregular
12.3-13.0	12 horizontal bedding joints that range from tight to 1/16" open, most are irregular.
13.2	horizontal bedding joint, 1/16" filled, planner

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BORING DC-85-124, FORT RILEY, KA (Cont.)

Depth (ft)	Description
(13.8-20.5)	Light gray-tan rock, with occasional small vugs
15.5	horizontal bedding joint, tight irregular
15.7-16.3	numerous approximately horozontal irregular joints, all are tight and have limonite(?) staining.
18.5-18.6	4 horizontal, irregular, tight bedding joints
20.4-20.5	3 horizontal, irregular, tight bedding joints
(20.5-25.0) (Bot.)	medium-dark gray mottled rock with no apparent joints

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BORING DC-85-125, FORT RILEY, KA

NX Borehole film Interpretation
Photographed from 4.0' to 25.0; hole dia. was 6" from 0.0 to 4.7'; NX dia. (3") below 4.7'. Bearings are based on magnetic north.

Depth (ft)	Description
(4.7-11.5)	Lt. gray-white rock with occ. small vugs in top zone; rock appears slightly weathered but competent,
5.2-5.3	Joint, strike N60°W, dip 35°NE, 1/16" partly open, irregular.
8.4	bedding joint, strike N10°W, dip 5°NE, tight; Joint is at contact with a 1" thick medium gray lense.
8.9	Horizontal bedding Joint tight to 1/16" partly open, irregular.
9.8-10.9	20 horizontal bedding Joints, tight, irregular
(11.5-12.0)	Medium gray rock, bed contact strike N40°W, dip 5°NE
(12.0-14.9)	Light gray-tan rock with occasional small vugs and numerous bedding Joints
12.1	bedding Joint, strike N30°W, dip 5°NE, tight, irregular
12.2	Joint, strike N40°W, dip 20°NE, 1/32"-1/16" filled, irregular.
12.3	bedding joint, horizontal, 1/32" tight, irregular.
12.4	bedding joint, horizontal, 1/16" partially open, irregular
13.4	bedding joint, horizontal, 1/16" partially open planner
13.9-14.0	medium gray rock lense, bedding strike N40°W, dip 5°NE
14.4	bedding joint, horizontal, 1/16" partly open, irregular
14.5-14.9	6 bedding joints, horizontal, tight, irregular
(14.9-16.3)	medium gray rock with occasional light gray lenses, possible occasional tight bedding joints.
(16.3-22.3)	light gray-tan rock with occasional small vugs

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BORING DC-85-125 (Cont.)

Depth (ft)	Description
17.7-18.1	numerous horizontal tight bedding joints
20.5	joint, strike N40°W, dip 15°NE, 1/32 filled, very irregular
20.6	joint, strike N40°W, dip 15°NE, 1/32 filled, very irregular
21.0-22.0	increase in vugs
22.3	2 horizontal bedding joints, tight irregular
(22.3-22.6)	Transition from light gray-tan rock above to medium dark gray rock below
(22.6-25.0)	Medium-dark gray rock, appears thinly bedded but no joints visible.

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APPENDIX B

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UNCONFINED COMPRESSIVE STRENGTHS AND COMPOSITION PROPERTIES FOR ROCK CORE FROM FORT RILEY, KANSAS

by

Jean C. Schumacher

Geomechanics Division, Structures Laboratory
U.S. Army Engineer Waterways Experiment Station
Vicksburg, MS 39180-0631

January 1986

Prepared for: Defense Nuclear Agency
Washington, DC 20305
Under Task Code RSRB, Work Unit 00037

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Table 1 gives a summary of the test results and compositional properties of these test specimens.

The first two columns in Table 1 record the number of the boring and the depth interval from which the specimen was taken. Column three gives a brief description of the core specimen, column four records the unconfined compressive strength of each specimen, and columns five through seven give the measured composition properties γ , w , and γ_d . The estimated grain density values in column nine were taken from The Handbook of Physical Constants*. The porosity (n) in column eight was calculated using the following equation:

$$n = \frac{G_s - \gamma_d}{G_s} (100)$$

where: G_s = grain density (gm/cm^3)
γ_d = dry density (gm/cm^3)

The results shown in Table 1 are graphically represented in Figures 1 through 4 for each boring. These figures show, for each boring, the variation with depth of material type, wet density, water content, unconfined compressive strength, and porosity.

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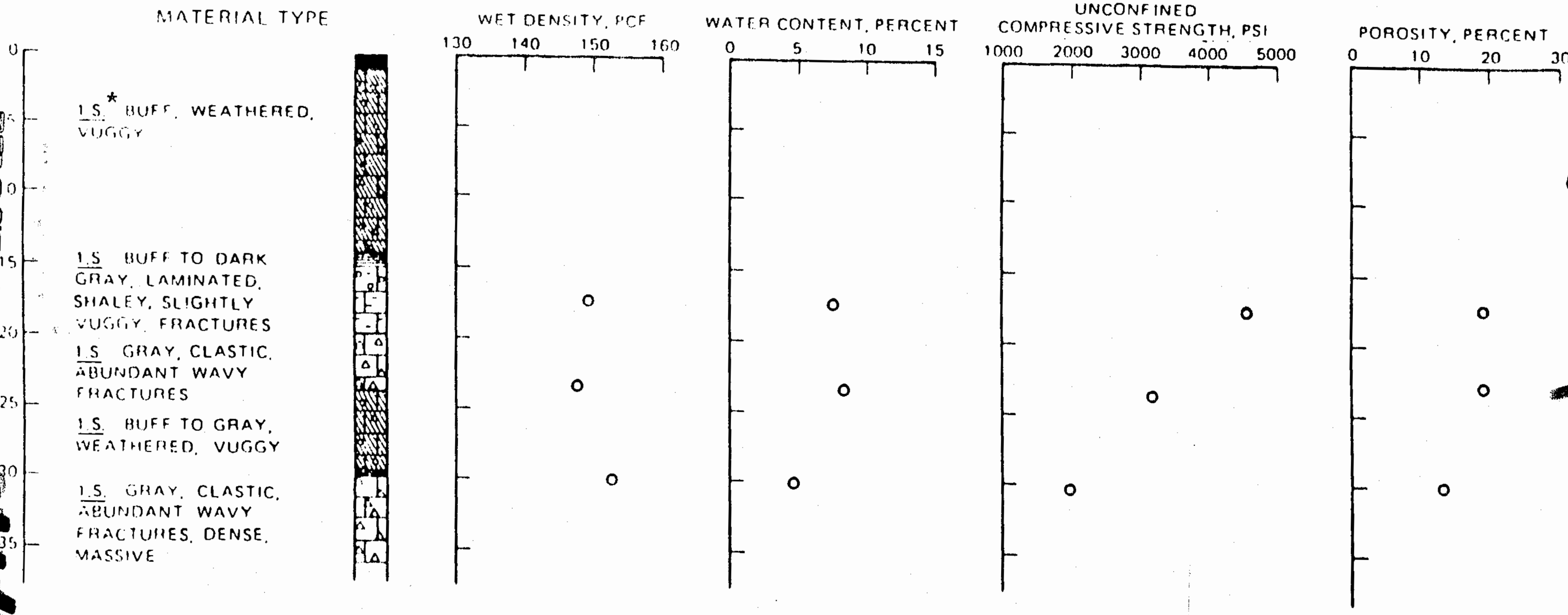
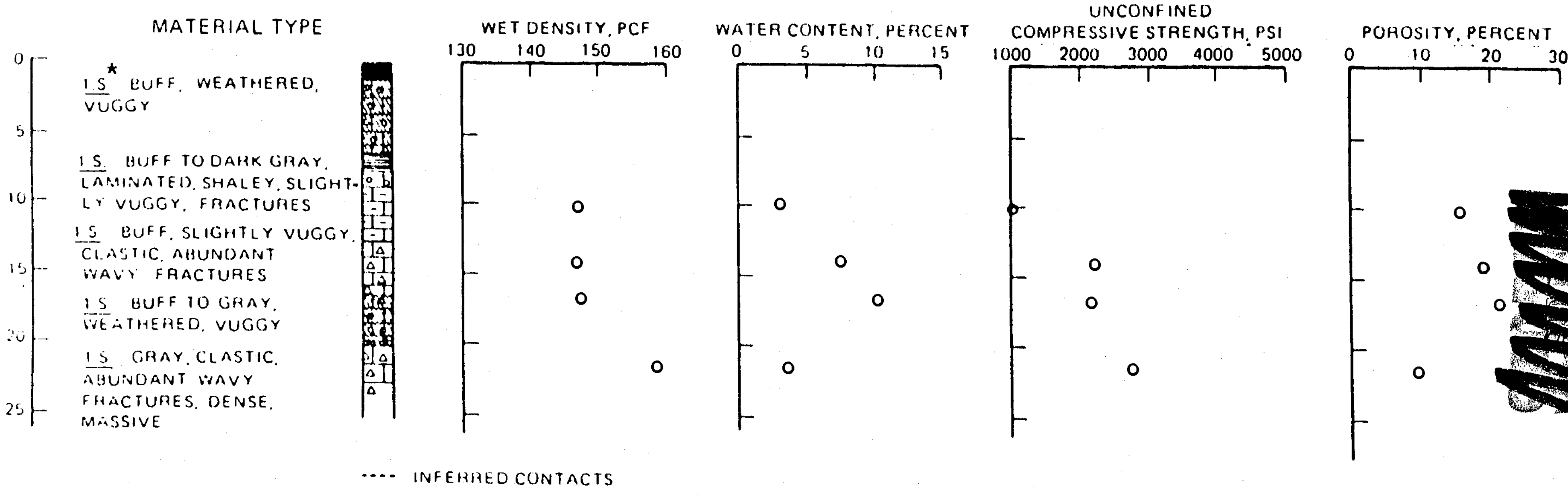
* The Geological Society of America, Inc.; Handbook of Physical Constants; 1966, The Geological Society of America, Inc., New York.



*1.S. = Limestone

Figure 2. Unconfined compressive strength and composition properties for core from borehole DC 85 122.



* l.S. = Limestone

Figure 3. Unconfined compressive strength and composition properties for core from borehole DC 85 124.

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